Pattern-oriented Approaches for Validating and Improving Satellite Precipitation Retrievals

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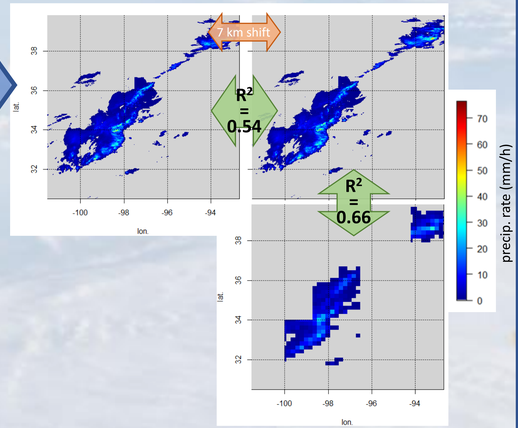
I) Precipitation patterns for product comparison and validation

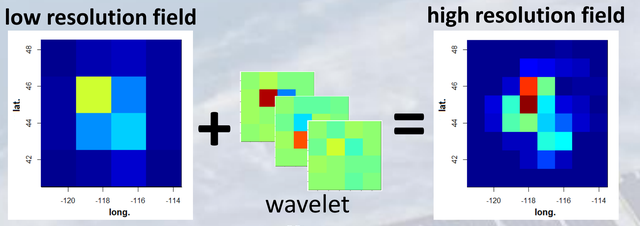
Pixel to pixel comparison may be misleading:

- weak characterization of mislocation errors
- "double penalty" phenomenon



Convolution filters can extract patterns from the fields:

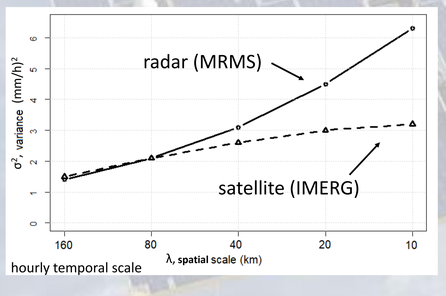
- In particular, wavelets can extract patterns at multiple scales to perform a multi-scale decomposition.



- Comparison of multiscale statistics:

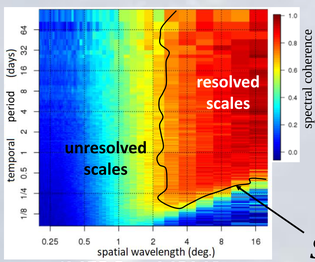
wavelet power spectrum

$$\frac{d(\sigma^2)}{d\lambda} = E[WC_\lambda^2]$$



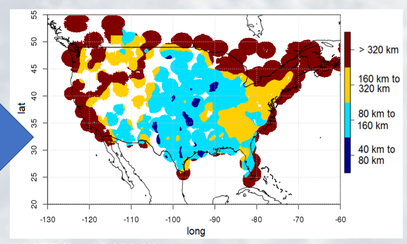
=> Satellite estimates generally show a deficit of variance at fine scales (smooth estimates).

- Spectral coherence (SC) between estimate and reference:



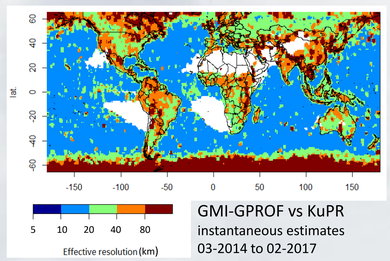
$SC^2 = 0.5$

Effective Resolution



IMERG vs MRMS
Eastern Continental US April-October 2017

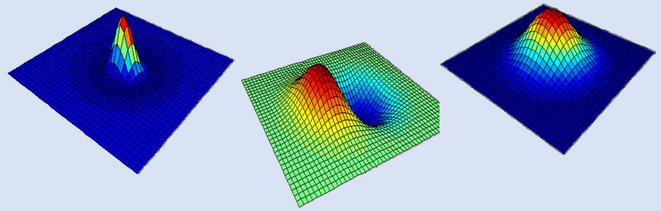
IMERG vs MRMS at hourly temporal scale
April-October 2017



GMI-GPROF vs KuPR
instantaneous estimates
03-2014 to 02-2017

Convolution filters

- Pattern extraction
- Spatial averaging / smoothing
- Spatial differentiation / edge detection / gradient extraction
- Multiscale decompositions (wavelets)



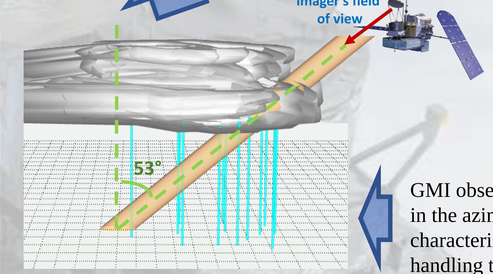
II) Brightness temperature patterns for improved retrievals

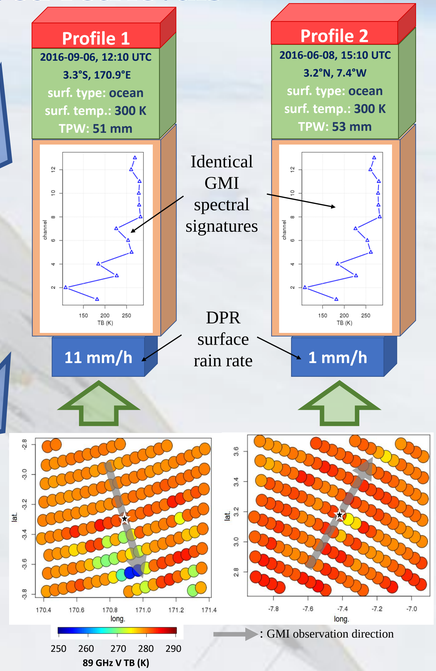
Instantaneous precipitation rate retrieval from passive microwave is an underdetermined inversion problem.

- Inherent uncertainty in the retrieved precipitation rate
- Additional information needed to resolve the uncertainty

The brightness temperature spatial patterns around the pixel of interest contain information to resolve the uncertainty.

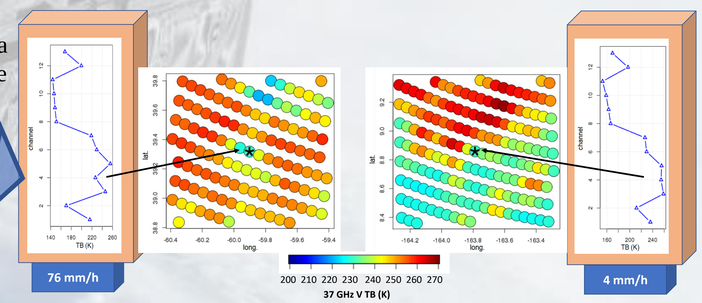
- Spatial gradients of T_B relate to precipitation
- Asymmetry in the relations between T_B gradients and precipitation from the observation geometry (53° Earth incidence angle)





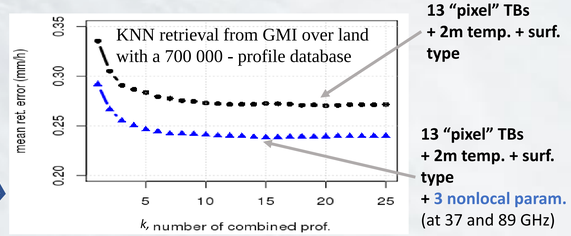
GMI observation geometry: computing the T_B gradient in the azimuthal direction of the observation helps characterizing the vertical structure of the system and handling the parallax shift for ice-sensitive channels.

For low-frequency channels (<40 GHz), a local depression of the T_B indicates a deep convective cell.



Convolution filters can be used to extract T_B spatial patterns and dynamics.

- Parameters resulting from the convolution of the T_B fields with pre-defined kernels are called "nonlocal parameters".
- Nonlocal parameters allow for enriched spectral signature and reduced retrieval uncertainty.



Guilloteau, C., E. Foufoula-Georgiou, and C. D. Kummerow, 2017: Global multiscale evaluation of satellite passive microwave retrieval of precipitation during the TRMM and GPM eras: effective resolution and regional diagnostics for future algorithm development. Journal of Hydrometeorology, doi:10.1175/JHM-D-17-0087.1.

Guilloteau, C., E. Foufoula-Georgiou, C. D. Kummerow, and V. Petković, 2018: Resolving surface rain from GMI high-frequency channels: limits imposed by the three-dimensional structure of precipitation. Journal of Atmospheric and Oceanic Technology, doi:10.1175/JTECH-D-18-0011.1.

Guilloteau, C., and E. Foufoula-Georgiou 2019: Beyond the pixel: using patterns and multiscale spatial information to improve the retrieval of precipitation from space-borne passive microwave imagers. Journal of Atmospheric and Oceanic Technology, *under minor revision.*